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(71) Applicant(s)
Kevin Doughty
Bryn Dedwydd, North Road, CAERNARFON, LL55 1BE, United Kingdom

Gillian Doughty
Bryn Dedwydd, North Road, CAERNARFON, LL55 1BE, United Kingdom

(72) Inventor(s)
Kevin Doughty
Gillian Doughty

(74) Agent and/or Address for Service
Kevin Doughty
Bryn Dedwydd, North Road, CAERNARFON, LL55 1BE, United Kingdom

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None

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(54) Abstract Title
Non-intrusive electronic determination of the orientation and presence of a person or infant in a bed, cot or chair using primary and secondary coils

(57) To determine the orientation or presence of a person or infant in a bed, cot or chair, a number of air-cored transformers are formed by a primary coil formed around a mattress or the seat or back of a chair, and secondary coils integrated into an item of clothing eg a belt, vest, nightdress, pyjamas, trousers or nappy. The secondary coils have different resonant frequencies and are located to define different pressure points on the body. The current position of the body is found by energising the primary coil with a series of different frequencies to find the secondary coil that couples best to the primary. A computer monitors the lying position so that action can be taken to avoid pressure sores or to prevent a baby lying in a position of increased risk of "cot death". The frequency of each secondary coil is determined by its area or number of coils, or by a capacitor.

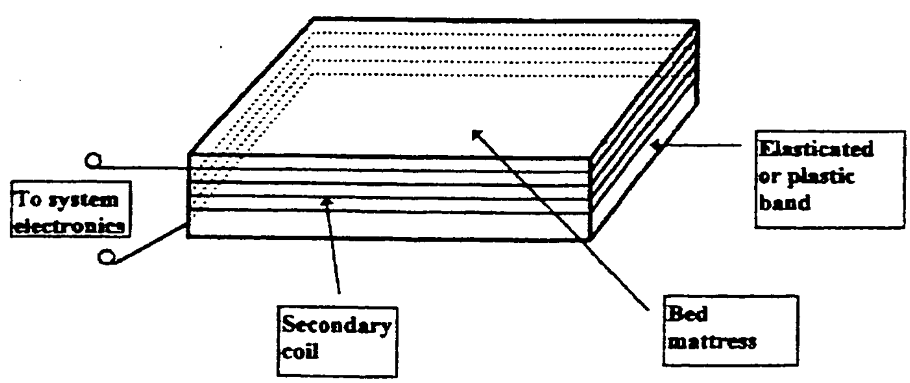

Figure 3: Tube arrangement for fabrication of primary coil

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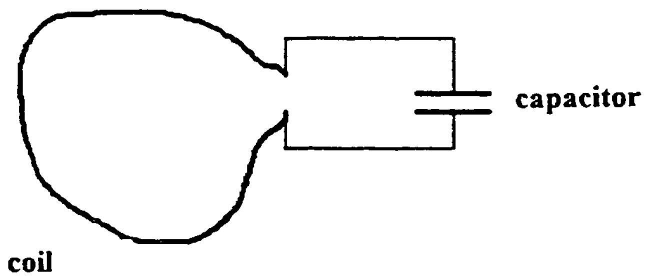

Figure 1: A coil shunted by a capacitor

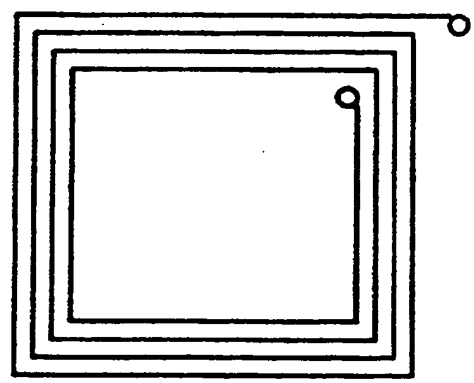

Figure 2: A helical coil structure for fabrication of PCB

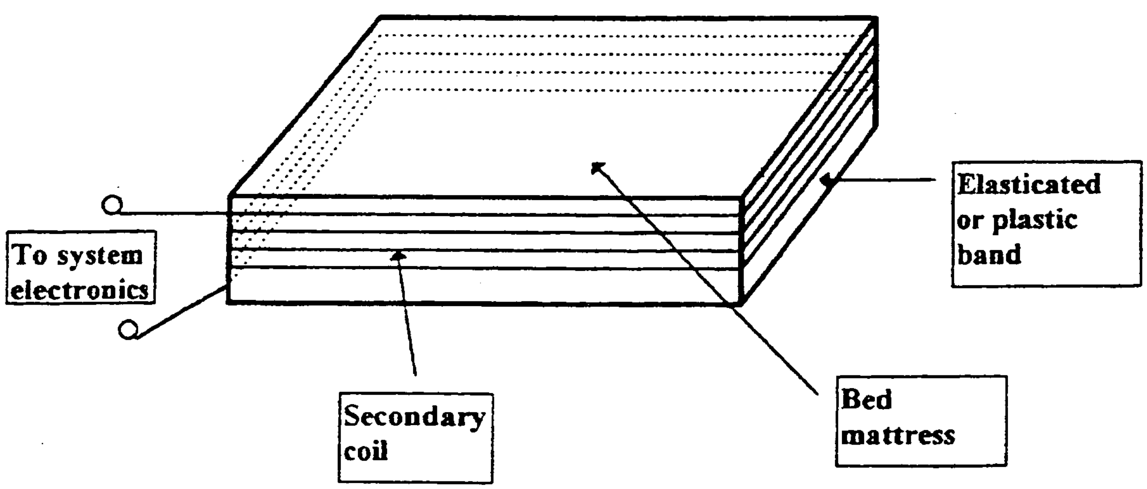

Figure 3: Tube arrangement for fabrication of primary coil

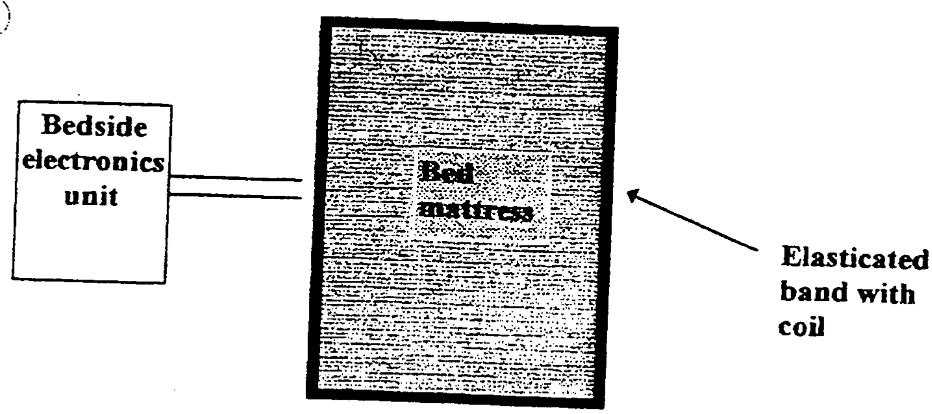

Figure 4: Arrangement of primary coil and drive electronics

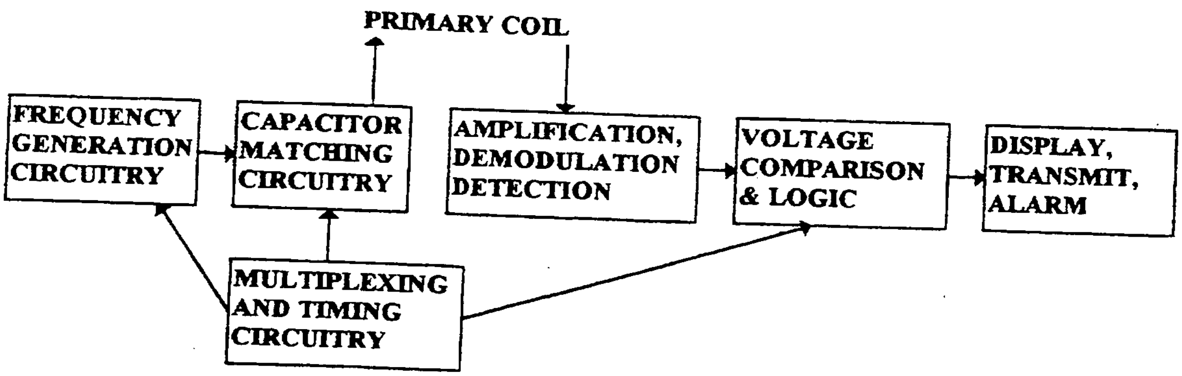

Figure 5: The Electronics System at the Bedside

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"A Method of Fabrication and Placement of Primary and Secondary Coils for the Electronic and Non-Intrusive Determination of the Orientation and Presence of a Person or Infant in a Bed, Cot or Chair"

Invention Summary

This invention is concerned with a method of producing tuned coils that can be fabricated into items of clothing and onto a bed, cot, mattress or chair in such a way that they form the secondary and primary inductors in a transformer arrangement. When several secondary coils with different resonant frequencies are used to define different body pressure points or lying positions, it is possible to determine the current position of the body by scanning through the frequencies to find the secondary coil that couples best to the primary (bed, cot, mattress or chair) coil. An electronic or computer processing unit can be used to manage the information on lying position so that nursing staff can take appropriate and continuous action to avoid the formation of pressure sores or to manage their treatment. In the case of infants, parents can be alerted to their babies lying in a position that might pose an increased risk of "cot-death" syndrome.

Background to the Invention

Pressure sores can form within days of a person being bed- or chair-bound; this may be the combined result of friction and a reduced blood flow to the flesh at pressure points such as heels, buttocks and shoulders. Standard procedures to reduce the incidence of such sores in hospitals and nursing homes involve the use of pressure reducing aids such as ripple beds and mattresses together with a dedicated procedure of regular turning so that pressure points are changed at relatively frequent intervals determined by the risk category of the patient. For example, an elderly person suffering from incontinence may need to be turned every 20 minutes in order to avoid tissue breakdown whereas a relatively fit person with good cardio-vascular function may tolerate 4 or 5 hours in the same position before the development of sores.

Unfortunately, the incidence of pressure sores continues to be high in developed countries both because of an ageing population and because it can be extremely difficult to operate a regime of turning patients regularly on under-staffed wards where acute issues take precedence over routine practices. In addition, the turning procedure can become compromised when the patient is himself able to change position between those occasions when he is turned by the staff. The result can be confusion and inappropriate attention ultimately leading to prolonged stress on certain pressure points.

In order to overcome the obvious deficiencies outlined above, a common practice is to turn a patient through 90 degree increments from front to left side, from left side to back, from back to right side and, then, from right side to front, where the position is clearly marked on the patient's record along with other vital signs such as temperature or blood pressure. This method has had some success in managing pressure areas but still suffers from a failure to remind staff of a need to turn the patient and, indeed, or whether they have moved themselves since the previous intervention. The present invention relates to a method of developing the necessary hardware to overcome these deficiencies in an automatic monitoring technique.

Automatic Position Monitoring

The position of a patient in a bed or in a chair may be determined either by:
(i) direct observation or
(ii) using an array of pressure sensors.
The observational technique may be made automatic by using a video camera, image capture hardware and artificial intelligence in the form of a computer system running dedicated software. Such a technique, though feasible, would not satisfy the requirements of non-intrusion which might be imposed for the benefits of the patients. It would also prove very expensive to implement on a large scale. In the latter method, pressure sensors would need to be mounted either on the body or, perhaps, on a suitable belt to be worn by the patient complete with electronic circuitry and battery supplies. The presence of such an intrusion might prove very distressing to the patient and might actually increase the incidence of pressure sores because of increased friction. Pressure sensors are also renowned for poor reliability of operation especially when compressed for long periods of time as is the case with hospitalised patients.

An alternative non-invasive method of position monitoring proposed in this application involves the use of induction coils placed about the relevant pressure contact points. There is no practical limitation on the number of sites for the location of these coils but at least four might be needed to represent the front, the back, the left side and the right side of the body. The addition of other coils would allow the definition of other, less likely, orientations. In a similar way, 3 coils would be needed to represent the three most likely seating position for someone in a wheel-chair. For a baby in a cot, it may only be necessary to define two positions - lying on the front and lying on the back.

These coils may, in principle, each be a different size, have a different number of turns and, consequently, have different values of inductance associated with them. However, for the purpose of explanation, let us assume that they are all have an inductance equal to some value Ls_i where the s refers to the fact that the coils will be the secondary (and passive) elements in a transformer arrangement. The subscript i allows the coil number to change as we move between the different coils. If the output of the coil is shunted by a capacitor of value Cs_i as shown in Figure 1 then this arrangement will give rise to a resonance at a frequency, f_i, where

$$f_i = 1/2\pi\sqrt{LCs_i}$$

It may be apparent that by choosing each value of the capacitor Cs_i to be different then this will define a different resonance frequency f_i. It follows that the same result could be achieved by using the same value of capacitance but ensuring that each coil had a different inductance associated with it.

If these coils were placed about the body then each part of the body might be associated with a specific resonance frequency. In practice, the placement of the coils in well-defined positions might best be achieved either by attaching them directly to the body (which would be intrusive bearing in mind the likely condition of the wearer) or by fabricating them into a garment. Bearing in mind the most likely lying positions and pressure points, it may be apparent that the coils may be placed on either a vest, or a belt or on a pair of pants. Indeed, they might be integrated into any item of night-clothing from a night-dress to pyjamas or, in the case of a baby, a nappy.

It is likely that a coil wound in the traditional way using thin wire on a former may be unsuitable for the proposed application both because of its weight, and its rigidity but also because of its essentially three dimensional nature which would cause discomfort to the wearer. Thus, in the present invention, linear coils are proposed. These may be in the form of helical structures sewn into the fabric of the clothing or belt using, for example, a sewing machine to stitch the thin insulated wire to the material as in embroidery, or formed on flexible printed circuit board material as shown in Figure 2. In our preferred arrangement, the coil structures are all fabricated on a thin layer of plastic which is also used as the dielectric of the capacitor connected across the ends of the coil; these are then insulated from the environment by a thin layer of sticky-backed plastic on each side. The entire band remains flexible and may then be attached to the respective item of clothing, preferably between two layers of material. The item of clothing can then be laundered without damaging the coils. The item of clothing may itself provide pressure relief for the patient by providing a cushioning effect either by the incorporation of soft and compliant sponge layers or by having an inflatable facility which provides an air-bed arrangement between the coils and the patient.

The size of the coils may be relevant in determining both the frequency of resonance and the magnitude of its interaction with an external electromagnetic field. The frequency range over which intelligent inductive coupling is permitted in the UK ranges from near d.c. up to about 300kHz. However, in order to make use of low-cost frequency generating circuitry, and to avoid the low frequency noise present in the audio range, the preferred frequency band of operation is 20kHz. to 80kHz. To ensure the availability of the preferred values of capacitance (realised either by forming a parallel plate structure across the thickness of the plastic substrate or by using an appropriate surface mount capacitor), this demands the use of coils with about 20 turns and an average radius of 100mm. although a wide range of sizes and shapes of coil would be possible.

In order to activate a secondary passive flat coil with r.f. energy from a primary coil, it is necessary to ensure that:

1) the secondary coil is smaller than the primary coil,
2) the secondary coil lies within the axis of the primary coil.
3) the secondary coil is physically very close to the primary coil (within its near field)
4) the secondary coil is parallel or nearly parallel to the primary coil, and
5) the primary and secondary coils are tuned to the same frequency.

It follows that if the primary coil is situated about the mattress of the bed or cot, then the above conditions might only be satisfied by those coils that are actually in contact with the mattress surface. Other coil interactions might be disallowed either because the secondary coils are too far from the bed (e.g. on the front of a patient lying on his back) or because they are oriented wrongly with respect to the bed surface (e.g. on the side of a patient who is lying on his back). Other interactions caused by loose fitting clothing which can be bent of distorted can be minimised by increasing the sizes of the coils.

Of course, if a large number of secondary coils is employed then there will be positions in which several of the coils satisfy the conditions described above at their particular resonant frequency. This would enable the lying position to be defined more accurately and, in principle, might permit the mapping of the lying position of a person who is bent into a strange position.

The primary coil may be wound directly around the frame of the bed though, in practice, the presence of the metal bed-frame can distort the field. It might also be produced in a linear manner by fabrication using the same methods described above for the secondary coils. However, in one of our preferred methods, the primary coil is formed in a tube arrangement as shown in Figure 3 where the wires are either stitched into an elasticated band or are wound around a band of plastic material which has been already pulled around the mattress of a bed. In the latter case, the wires are then located at various locations around the circumference using stitching or sticky tapes. Additional sticky tapes are used to isolate the coil. The coil might similarly be fabricated into a complete sheet.

The structure described above might also be realised by using ribbon cable (containing typically 24 or more separate parallel wires) wrapped around the mattress either once or several times. The ends of the cable are supplied with standard connectors, one male and one female. The connectors are mated together but in a manner in which they are all displaced by one wire i.e. male connection 1 attaches to female connection 2. In this way one connection is unattached on both connectors and these form the ends of the coil.

In the solenoid-shaped primary coil arrangement described above, the electromagnetic field extends a few millimetres into the mattress of the bed. This ensures that some interaction will occur even if the patient has sunk slightly into the body of a soft mattress. The ends of the primary coil are connected to a bedside electronics control unit shown in Figure 4. It may be apparent that the primary coil may be considered to be an inductive antenna which is capable of transmitting and of receiving a wide-range of frequencies depending on the impedance placed across its ends.

The arrangement described above can also be applied to a patient sitting upright in a chair and, especially, for one confined to a wheel-chair for much of the day. In this case, it is possible for two primary coils to be present, one around the seating part of the chair and a second around the back-rest region. These could independently interact with coils placed on a garment such as pants where the secondary coils might cover various regions of the buttocks and hips and with those on a vest where the secondary (sensing) coils are about the shoulder blades and back. In these cases, the number of sensing position needs to be increased in order to improve the resolution and in order to distinguish between a smaller set of possible positions.

The Electronics System

This is shown in Figure 5 and consists of a frequency generation unit that is capable of scanning the frequency range of interest either in steps or continuously. The advantage of step-wise scanning is that, through the use of multiplexers, it permits the exact identification of the frequency being produced at any instant in time. Associated with each frequency is a value of a capacitor, Cp_i, which has been selected to produce resonance at the frequency, fi, of the corresponding secondary coil. This capacitor is switched across the primary coil when the corresponding frequency is generated. The voltage produced across the primary coil is amplified and demodulated using a germanium diode before the carrier signal is removed. The next stage involves a comparison of this voltage with that measured in the absence of a coupled secondary coil. The presence of a matched secondary coil will cause energy transfer which will be observed as a reduction in the voltage measured across the primary coil. In this way, it is possible through the use of logic to determine whether or not each coil is in the position for optimum coupling i.e. on the bed and parallel to the mattress.

The scanning between the various resonant frequencies can be performed continuously and at a rate limited by the settling time of the electronic circuitry. Generally, it would be performed at such a rate that all the frequencies are scanned through in 1 second or less so that a quasi-continuous position can be derived. However, a relatively slow scanning of the frequencies will enable the system to disregard those movements which may be associated with disturbed sleep rather than with changed position thus minimising the possibility of detecting motion as an indicator of changed position. Conversely, a shorter scanning time may be used to measure the sleep disturbance through an analysis of the frequency of changes in position.

The final section of the electronics circuitry is the display and decision circuitry. In its simplest form, this compares the status of the logic described above with that measured during the previous scanning sequence. A change in the logic state of any coil can only be achieved as a result of turning or of movement in the vertical plane. In the former case, this would be characterised by the excitation of another different coil or coils which would imply a new lying position. In the latter case, it would imply sleep disturbance which might need nursing attention

or, in situations involving patients with mental rather than physical problems, might imply that a patient has got out of bed. This data might be displayed simply by using an illuminated LED to show any coil which is activated; this could be labelled as a current lying position.

Additional circuitry could be added to determine the time span that has elapsed since the last change in this status. This time could be compared with some pre-set time which has been deemed appropriate for that particular patient and governed by their risk status as far as the development of pressure sores is concerned. If there has been no movement within this time then an alarm may be raised in one of a number of ways including flashing lights at either the bed or the nurses' station, an audible warning, or a direct paging of the nursing or caring staff whether they are in the hospital or nursing home or, indeed, in community care, in a mobile facility. The carers may then be alerted to the need for action and the system will automatically reset when the patient's position is changed. Communication between the bed-side electronics unit and the carer might then be by one of a number of media including hard-wire, r.f. telemetry, modulation of the neutral line of the mains, or by fixed or mobile telephones.

For wheelchair users who may have no feelings in their lower limbs but who may be capable of readjusting their position without, necessarily, the need for outside assistance, the alarm may present the patient himself with a discrete reminder to reposition himself.

Additional Analysis and Alarm Functions

Although, in its simplest form, the hardware solution proposed above may be used to manage the turning and movement of patients in line with recommendations for their category of risk, it may be apparent that it may become difficult to implement in a large ward where nurses need to monitor potentially large numbers of patients simultaneously. In these cases, it may not be sufficient to indicate to the care staff when a particular patient needs to be turned as such routine tasks might, on occasions, have to wait until other more acute problems are dealt with. In such cases, the quality of care can become compromised and, indeed, may become arbitrary unless objective measures of care can be included.

By replacing the role of the comparitor logic described above with a personal computer and interfaces then it becomes possible to both monitor a number of patients simultaneously and to prioritise attention in order to minimise the collective risks. This would be achieved by combining the effects of delay with the history of turning and the relative risk of each patient in a simple scoring system.

A computer system would also be capable of measuring the response of the nursing staff to the system alarm by measuring how long after an alarm the system is reset by the action of turning. This information can be used as the basis of a "quality of care" index which might be used to compare different facilities.

The statistics of the sensed lying position may be useful both for research purposes in studying the preferred orientation of patients who have some mobility and in determining the efficacy of other forms of treatment for pressure sores such as ripple mattresses. If a patient already has a pressure sore on one side, or has a wound following accident or surgical intervention, which forbids him from lying in a particular way, then a computerised system can be programmed to provide an alarm to alert staff if he actually moves into that position. This alarm may be

different to the normal pressure area management alarm and can be given different priority in the system.

It follows that the preferred lying position of each patient who is able to reposition themselves without help may also be determined so that areas of soreness may be detected without the need for reporting by the patient themselves. This may be particularly relevant for elderly patients where multiple pathologies are likely to be present but unknown to care staff.

Finally, the complete history of patient movement can be archived as a record of care for future use in cases of negligence or in claims for compensation for inadequate care. In such cases, the records might be regularly down-loaded to some independent third party using a secure communication network.

Claims

1) A method of fabricating a number of air-cored transformers consisting of:

(a) one or more primary coils which can be formed around a bed/cot mattress or around the back and seat of a chair,

(b) a number of secondary coils which are integrated into an item of clothing such as a belt, a kummerbund, a vest, a night-dress, pyjamas, trousers, or a nappy and

(c) some electronic drive, amplification, detection, demodulation, comparison and logic circuitry,

where the coupling between specific primary and secondary coils can be used to determine the position of the patient in a bed, cot or chair.

2) A method as described above in which the primary coil may be produced on a sheet or a band of cloth or plastic that can be stretched over the mattress of a bed or the seat or back of a chair by embroidery using hand or machine-sewing techniques in such a way that bed sheets (or cushions) can be removed for laundering without or replaced without disruption.

3) A method as described in 1) in which the primary coil may be attached to a sheet or a band of cloth or plastic using one of a number of techniques such as sewing, glueing or enclosing with a layer of plastic or cloth.

4) A method as described in 1) in which the primary coil may be formed using ribbon cable stretched around the mattress either once or a number of times, the ends of which are electrically connected using displaced male and female connectors in such a way that the first wire on one and the last wire on the other form the contacts for connection to the electronic drive system.

5)A method as described in 1) in which the secondary coils may be sewn into an item of clothing using embroidery using hand or machine-sewing techniques .

6) A method as described in 1) in which the secondary coils may be formed by sewing or embroidering on plastic or other material which may then be attached either individually or as a complete assembly onto an item of clothing.

7) A method as described in 1) in which the secondary coils may be formed using flexible PCB techniques and which may be attached to items of clothing for location in the appropriate position on the body when worn.

8) A method as described in 1) in which the secondary coils are mounted on a belt or a nappy that its worn around the waist or hips of the patient.

9) A method as described in 1) in which the resonant frequency of a secondary coil is controlled by the value of the capacitor that is connected across its ends.

10) A method as described in 1) in which the capacitor connected across the ends of the secondary coil is integrated into the plastic which forms the substrate for the coil.

11) A method as described in 1) in which the resonant frequency of a secondary coil is controlled by the area of the coil.

12) A method as described in 1) in which the resonant frequency of a secondary coil is controlled by the number of turns of the conductor wire.

13) A method as described in 1) in which the resonant frequency of a secondary coil is controlled by the cross-sectional area of the conductor.

14) A method as described in 1) in which each secondary coil has a different and unique frequency.

15) A method as described in 1) where the primary coil can be tuned to the resonant frequency of a secondary coil by the addition of suitable capacitance.

16) A method as described in 1) where the frequency of energising can be switched between the resonant frequencies of the secondary coils.

17) A method as described in 1) in which the coupling between a primary and a secondary coil may be measured by detecting the voltage drop across the terminals of the primary coil.

18) A method as described in 1) in which coupling is achieved only when the secondary coil lies within the area defined by the primary coil, lies parallel to the plane and is physically very close to the plane and when the primary coil is energised with the resonant frequency of the secondary coil.

19) A method as described in 1) which enables the position and orientation of a secondary coil to be determined because of its interaction with the primary coil at its resonant frequency.

20) A method as described in 1) which enables the pressure points of a patient to be determined at any instant because of the coupling of an array of secondary coils about a person's body and one or more primary coils located on a bed or chair.

21) A method as described in 1) which allows the time spent in one position in a bed or chair by a patient to be monitored using the interactions of the secondary and primary coils at resonant frequencies.

22) A method as described in 1) which can manage a person's pressure areas by alerting a carer and/or a patient of the need to turn the body after a pre-determined time in one position.

23) A method as described in 1) which can be used to alert carers if a patient has turned into a position which may put at risk wounds or sores caused by accident, surgery or other causes.

24) A method as described in 1) which may be used to measure the response times of care staff.

25) A method as described in 1) which may be used to measure sleep disturbance..

26) A method as described in 1) which may be used to detect patients who have got out of bed or a chair.

27) A method as described in 1) which may be used to prioritise the time of nursing staff in dealing with routine and emergency functions.

28) A method as described in 1) which may be used to provide statistical information on the resting behaviour of patients.

29) A method as described in 1) which may be used to produce a historic and documentable record of the care afforded to patients.

30) A method as described in 1) which may be used to provide community carers with the opportunity to prevent the occurrence of pressure sores.

31) A method as described in 1) which may be connected to a telecommunication system in order to summon the services of a remote carer.

32) A method as described in 1) which may be used by parents to ensure that their infants lie in a particular orinetation in their cots in order to reduce the likelihood of cot death syndrome.

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Examiner: Bob Clark
Date of search: 4 December 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G1N (NAEC, NENX)

Int Cl (Ed.6): A61B 5/103, 5/11; G01D 5/20

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	None	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.